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A Comparison of the Relative Abundance and Size of Juvenile Winter Flounder, *Pseudopleuronectes americanus*, in Natural Intertidal and Anthropogenically Altered Marina Habitats

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Abstract

The relative abundance and size distributions of juvenile winter flounder, *Pseudopleuronectes americanus*, were compared in two areas; an anthropogenically altered marina basin and a natural intertidal flat habitat. Winter flounder were sampled from March through November 1990–95 with a 1.0 m beam trawl. No significant difference was observed in catch-per-unit-effort between areas but significant differences were found between seasons. Relative abundance (number of flounder/ m^2) increased from spring (0.007 marina and 0.011 intertidal flats) to summer (0.059 marina and 0.051 intertidal flats) and then declined slightly in the autumn (0.047 marina and 0.027 intertidal flats). Relative abundance was similar between areas from 1990–95 but differed between years. Length frequency distributions of winter flounder were similar between areas for all seasons but mean sizes were statistically different in summer. These results suggest that juvenile winter flounder are equally abundant in both natural intertidal habitats and marina basins, indicating that both could serve as nursery areas. However, more specific research is required to resolve the relative importance of marinas and the factors involved in utilization of each habitat.

Key words: flounder, marina, nursery, intertidal flats, *Pseudopleuronectes americanus*.

Introduction

Marina basins are anthropogenically altered habitats that have become a conspicuous part of the coastal zone throughout Long Island Sound, USA. A rise in recreational boating has resulted in an increase in the demand for the expansion and construction of boat marinas. In most cases, creation of these marinas involves removal of integral parts of the existing ecosystem such as salt marshes, seagrass beds and intertidal areas which are utilized by a variety of fishes and invertebrates as nursery habitats (Nixon, 1980; Boesch and Turner, 1984, Heck *et al*., 1989).

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Previous studies on marinas have suggested that they do not totally displace marine life and indeed may serve as habitat for juvenile fishes. Nixon *et al*. (1973) reported a high abundance of juvenile fish in a marina in Warwick Harbor, Rhode Island, USA and proposed that marinas may function as a refuge similar to salt marshes. Cardwell *et al*. (1978) compared fish communities in the Skyline Marina in Puget Sound, Washington, USA with an adjacent subtidal, eelgrass habitat of Burrows Bay and found that the marina had a more diversified and species rich assemblage. Mroczka (1991) recorded 8 species of juvenile fish during a 7-month survey of a marina basin in Long Island Sound and suggested that the high abundance of fish, relative to an intertidal habitat, was due to refugia provided for juvenile fishes by the marina pilings and docks.

The winter flounder, *Pseudopleuronectes americanus*, is an abundant demersal fish of the Long Island Sound estuarine system and is an important commercial and recreational fish (Smith *et al*., 1989). During early life history stages, winter flounder utilize shallow water intertidal coves and marshes as nursery habitat (Pearcy, 1962; McCracken, 1963; Poole, 1966). Since many of these areas have been degraded physically and chemically (O'Connor and Huggett, 1988; Burns, 1991), it is imperative to describe potential juvenile winter flounder habitat. Because of the recent concern about the role that habitat destruction and marine pollution have on fish stocks (Grosse *et al*., 1997), this description of juvenile winter flounder habitat should be part of a larger program of successful management of the coastal zone to develop a clear understanding of all types of ecosystems which fish may utilize. The purpose of this study is to provide a quantitative comparison of the relative abundance and size of juvenile winter flounder in two habitats of Clinton Harbor, Clinton, Connecticut; an anthropogenically altered marina basin and unaltered intertidal habitat.

Study site

Clinton Harbor, Clinton, Connecticut, USA is centrally located along Connecticut's southern coastline on Long Island Sound's northern border (Fig. 1). The inner harbor occupies approximately 740 000 m^2 and has a mean tidal range of 1.5 m. Freshwater discharge into the harbor is from the Hammonassett, Indian, and Hammock Rivers. The marina is located approximately 1.6 km from the entrance to Clinton Harbor near the mouth of the Hammonassett River. The marina basin comprises an area of approximately 30 000 m^2, has berth facilities for up to 400 boats, and is dredged annually during January–March to a mean low water of 2.5 m (Smith, 1991). The adjacent intertidal flat habitat occupies 80 000 m^2. Water depths within the marina basin averaged 3.1 m while depths on the intertidal flats averaged 1.3 m. Sediment grain size was similar between both habitats comprising between 80–90% silt clay, with the remaining 10–20% fine sand and shell (Mroczka, unpubl. data).

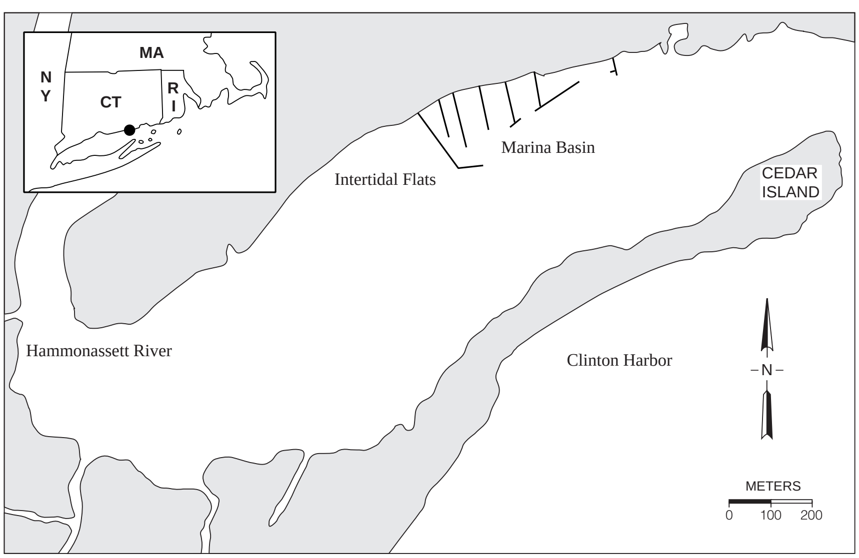

Fig 1. Clinton Harbor, Clinton, Connecticut and the locations of the marina basin and intertidal flat habitats.

Methods and Materials

Winter flounder were sampled within each area 2–4 times per month from March through November 1990–95. Samples were taken using a 1-m beam trawl made of knotless 6.4 mm nylon mesh with one tickler chain at mean high water (±2.0 hr) during daylight hours.

Environmental parameters (temperature, salinity, dissolved oxygen) were monitored with a Hydrolab Datasonde 1 and Datasonde 2 or were measured with a YSI model 33 temperature-salinity-conductivity meter. Dissolved oxygen concentrations were also determined using the azide modification of the Standard Winkler Titration Method (Rand *et al.*, 1975).

The relative abundance of winter flounder within each area was based on 2–3 replicate trawls per area. The within area catch-per-unit-effort (CPUE) were calculated as the grand mean (±s.e.) of winter flounder captured per m^2. Effort was standardized by establishing routine distances with location marks on the docks and shore. The towing speed was approximately 1 knot from fixed point to fixed point. Immediately after the trawl was retrieved, winter flounder were sorted out and total length (TL) to the nearest 0.1 mm was recorded for each specimen.

Data analyses

Length/frequency distributions within each area were pooled over all years sampled and grouped by season (e.g. spring: March, April, May; summer: June, July, August; autumn: September, October, November). The monthly CPUE data were grouped into season and tested for differences among area and season using a two factor analysis of variance. The assumptions of normality and homogeneity of variance were tested using normal probability plots of residuals and plots of residuals *vs* predicted values (Neter *et al.*, 1990). If data did not meet assumptions, transformations were performed following recommendations in Zar (1984).

Results

A total of 1 261 winter flounder were captured during the study period comprising 72.0% of the total catch (Table 1). Other species for which catch was 3.0% of the total or more were northern pipefish, *Sygnathus fuscus*; smooth flounder, *Pleuronectes putnami;* striped searobin, *Prionotus evolans;* and oyster toadfish, *Opsanus tau.*

TABLE 1. Total catch composition (percent of numbers caught) from the marina basin and intertidal flats, 1990–95.

Scientific name	Percent contribution
Anguilla rostrata	0.1
Apeltes quadracus	0.2
Centropristis striata	0.6
Gobiosoma spp.	0.2
Menidia menidia	1.1
Microgadus tomcod	0.2
Myoxocephalus spp.	1.1
Opsanus tau	3.2
Paralichthys dentatus	1.0
Pholis gunnellus	0.4
Pleuronectes putnami	4.0
Prionotus evolans	3.9
Pseudopleuronectes americanus	72.0
Scophthalmus aquosus	1.0
Sphoeroides maculatus	0.7
Sygnathus fuscus	8.7
Tautoga ontis	0.1
Tautogolabrus adspersus	0.1
Trinectes maculatus	1.4

Physical Parameters

The marina basin and intertidal flats exhibited similar abiotic characteristics throughout the study period (Table 2). Water temperature ranged from 2 to 32°C with warmer temperatures in July and August (25–32°C) and cooler temperatures (2°–15°C) occurring from March–May. Salinity averaged 21–25 ppt with decreases from September–November. Marina basin dissolved oxygen levels generally exceeded 6.0 mg per l and never fell below 3.9 mg per l. However, dissolved oxygen levels did reach lower levels on the intertidal flats but only infrequently during summer months.

Relative abundance of winter flounder

Because much of the trawl data contained 0 catches, the CPUE data were log transformed [$log_{10}(x+1)$] prior to analysis (Zar, 1984). No significant difference was observed in CPUE between areas but significant differences were found between seasons (Table 3). Relative abundance was highest during summer and lowest in spring (Fig. 2). The average CPUE (untransformed flounder/m^2) increased from spring (0.007 marina and 0.011 intertidal flats) to summer (0.059 marina and 0.051 intertidal flats) and then declined slightly in the autumn (0.047 marina and 0.027 intertidal flats).

Relative abundance was statistically similar between areas for all years sampled but differed between years (Fig. 3). CPUE was highest in both areas in 1992. There was little difference between the other years for the marina but 1993–95 was generally lower than 1990–91 for the intertidal flats.

TABLE 2. Physical and chemical characteristics of study sites in Clinton Harbor, Clinton, Connecticut.

Location	Area (m^2)	Mean depth (m)	Temperature range (°C)	Salinity range (ppt)	Dissolved oxygen range (mg per 1)	Sediment type
Marina Basin	~30 000	3.1	3–31	4–33	3.9–12.3	90% silt/ clay 10% fine sand shell
Intertidal flats	~80 000	1.3	2–32	0–31	0.0–12.1	80% silt/clay 20% fine sand shell

TABLE 3. Results of two-factor ANOVA for the effects of area and season on $log_{10}(x+1)$ CPUE and area and year on $log_{10}(x+1)$ CPUE. (* denotes significant value.)

Factor	Dependent	df	F-value	P-value
Area	$log_{10}(x+1)$ CPUE	1	1.43	0.233
Season		2	16.24	0.0001 *
Area•Season		2	1.14	0.329
Residual		272		
Area	$log_{10}(x+1)$ CPUE	1	2.89	0.091
Year		5	17.98	0.0001 *
Area•Year		5	2.38	0.039 *
Residual		266		

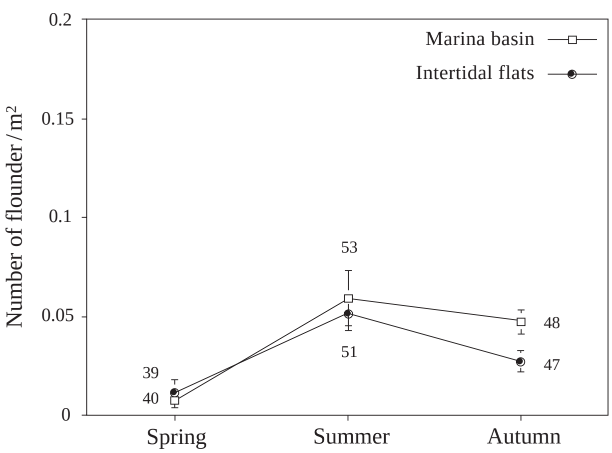

Fig. 2. A comparison of the relative abundance (±s.e.) of winter flounder by areas and season for years 1990–95. Numbers adjacent to each season represent the total number of tows taken for each area.

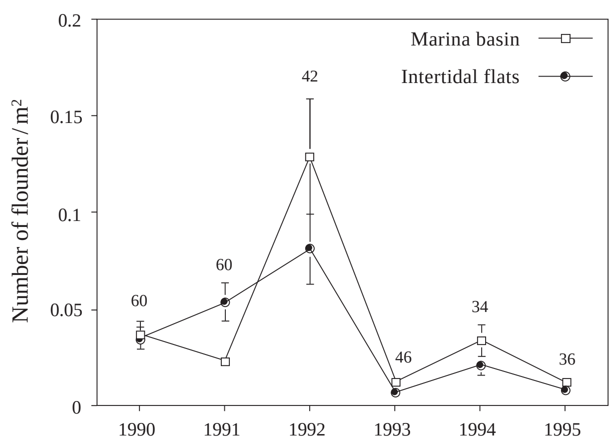

Fig. 3. A comparison of the relative abundance (±s.e.) of winter flounder by area and year for combined seasons. Numbers above each year represent the total number of tows taken for areas combined.

Length-frequency Distribution

The seasonal length-frequency distributions for winter flounder were similar between areas. Generally, a seasonal distribution pattern of total lengths (TL) from March through November was observed (Fig. 4). In spring, a mode near 40 mm was detected. Average size of winter flounder collected was 44.1 mm TL (±29.5 s.d.) and 45.3 mm TL (±29.9 s.d.) within the marina basin and intertidal flats, respectively. The summer distributions showed peaks at 40 and 60 mm TL for the marina and intertidal flats. Mean size increased to 49.6 mm TL (±24.3.d.) within the marina basin and 53.7 mm TL (±25.7 s.d.) within the intertidal flats. During autumn, distinct modes was found at 80 mm, but modes were also found at 60 and 100 mm. Average size of winter flounder during autumn was 74.9 mm TL (±25.6 s.d.) and 75.6 mm TL (±33.7 s.d.) within the marina and intertidal flats, respectively. The mean size of winter flounder (log_{10} transformed) was not statistically different between areas for spring and autumn (unpaired t test: $p \geq 0.05$) but was statistically different in summer (unpaired t test: $p < 0.01$).

Following the age/length relationship provided in Northeast Utilities Service Company (1989), we estimated both habitats were dominated by age 0 winter flounder. Throughout the sampling year, age 0 flounder comprised 92%, 95.8%, and 88.9% of the population for spring, summer and autumn, respectively. Age 1 flounder constituted 6.1%, 3.3%, and 8.9% of the population for spring, summer and autumn, respectively. Age 2+ flounder included 3.5% of the population for all seasons combined.

Discussion

Relative abundance estimates for winter flounder within the marina basin and intertidal flats were lower than estimates provided in other studies. Pearcy (1962) measured densities up to 1 flounder/m^2 in the Mystic River, Connecticut, USA and Van Guelphen and Davis (1979) measured densities of 0.2 flounder/m^2 in Newfoundland, Canada. Lower densities found in our sampling areas do not necessarily reflect a lower relative abundance in our study site. Differences in gear types may produce differences in relative population size. Moreover, Poxton and Nasir (1985) found that various sediments will affect the efficiency of trawls, with muddier sediments causing beam trawls to fish less efficient by clogging the net with mud if a minimum trawl speed was not maintained. Flatfishes are also sensitive to the pressure wave produced in front of the net (Kerstan, 1991) and some may have sought refuge in areas inaccessible with our trawl. Estimates of catchability of our 1 m beam trawl were not within the scope of this study.

Variation in year-class strength can be an important as a source of bias in estimates of relative abundance between habitats (Kerstan, 1991). However, this was not the case in this study. No differences in relative abundance were found between habitats in any years. Abundance differences between years were likely only artifacts in the variation in recruitment among years.

A similar trend in seasonal relative abundance was observed for winter flounder for both areas. The lowest relative abundance was found in spring, increased in summer months, and then declined slightly in autumn. Young-of-the-year fish that are likely to have recently settled out from their planktonic stage made up the bulk of the abundance in spring. During early summer, the increase in abundance was from older winter flounder (~Age 6–9 months) that are likely to have moved into both the marina basin and intertidal flats from other areas or come out of their winter burial in the mud. Larval settlement occurs during March–May (Pearcy, 1962; Richards, 1963) and older juveniles are usually present by July (Pearcy, 1962) in Long Island Sound. The decline in abundance during autumn likely reflects a seasonal movement of larger fish to shallow offshore coastal areas or among smaller individuals to bury in shallow sediments (Pearcy, 1962; McCraken, 1963; Tyler, 1971).

Although there is movement with the tides on the intertidal flats, winter flounder likely remain within each respective habitat once established. Young winter flounder are not as adversely affected by temperature and salinity changes and thus do not migrate as extensively as adults (McCracken, 1963; Poole, 1966). Saucerman and Deegan (1991) reported limited movements of young-of-the-year winter flounder once they have established themselves in their nursery habitat despite changes in temperature. Whether there is movement of winter flounder between the marina and adjacent intertidal flat has yet to be determined.

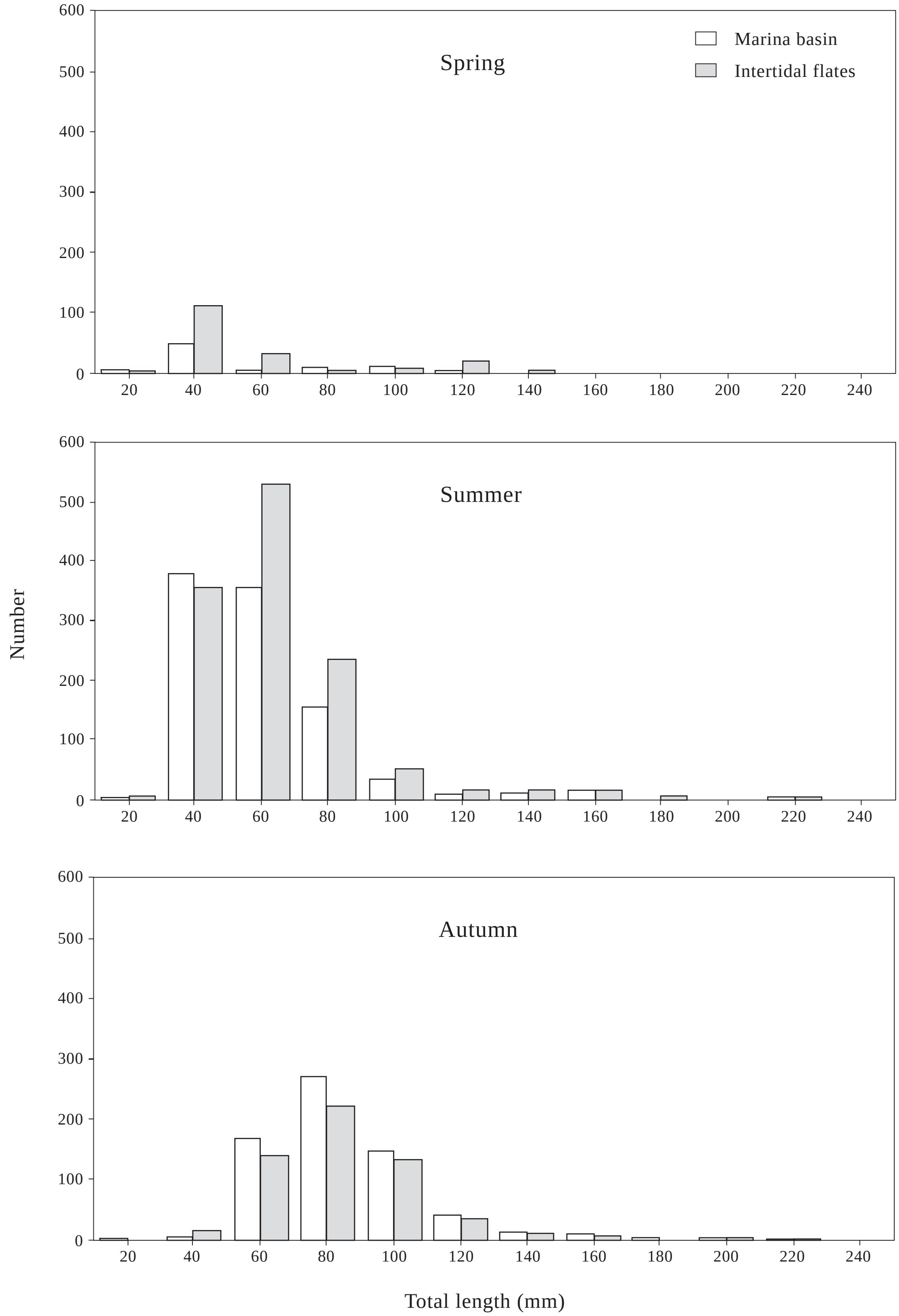

Fig. 4. Length frequency distribution of winter flounder collected from the marina basin and intertidal flats during spring (Mar–May), summer (Jun–Aug), and autumn (Sep–Nov), pooled over all years sampled.

Although other studies (see review in Klein-Mcphee, MS 1978) have shown that winter flounder segregate by size along a depth gradient according to differential preference to temperature and light, no evidence was found to show that flounders prefer one habitat to another due to other abiotic factors. The similarity in temperature, salinity, and sediment type between study areas may explain the similarity in relative abundance and size of winter flounder between habitats.

It has been demonstrated that areas having the highest prey availability were the most important in selection of an area by juvenile flatfishes (Poxton *et al*., 1982; Poxton *et al*., 1983). Macrobenthic community structure and macroinvertebrate density of the marina basin and intertidal flats appears to be relatively high. Pellegrino and DeSanto (1990) and Pellegrino (unpubl. data) reported overall mean macroinvertebrate densities of 36.7 individuals/ $0.04m^2$ and 74.5 individuals/$0.04m^2$ for the marina basin and intertidal flat habitat, respectively with polychaetes being the dominant organism. Therefore, juvenile winter flounder may be utilizing these habitats as a feeding area.

Although availability of food may be a factor in selection of a habitat, evidence suggests that predator avoidance may be more important for juvenile fishes (Blaber and Blaber, 1980). Juvenile winter flounder are subject to predation by various predators such as bay shrimp *Crangon crangon*, (Witting and Able, 1993), summer flounder *Paralichthys dentatus*, and cormorants, *Phalocrocorax auritus* (Pearcy, 1962). Tyler (1971), Wells *et al*. (1973), and Black and Miller (1991) reported that intertidal flats are used extensively by juvenile winter flounder as a refuge from predators. Predation on flatfishes by larger teleosts is likely decreased on intertidal flats, however predation by birds such as herons is increased (Armstrong, 1997). Conversely, juvenile flounder may be utilizing the marina basin due to the array of floating docks that would increase protection from birds but predation by larger teleosts would be increased. Thus, both habitats may be equal in terms of providing a refuge from predation.

The results of this study demonstrate that marina construction does not necessarily negatively impact the relative abundance of young-of-the-year and juvenile winter flounder. However, it is important to note that each area must be evaluated individually to better understand the mechanisms by which juvenile fishes select and utilize habitats. Further, more specific research is required to resolve the overall importance of marina systems, especially in terms of primary and secondary productivity.

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